Karlsruhe Institute of Technology

Analysis of cosmic rays below the Ankle with the high elevation Auger telescopes (HEAT)

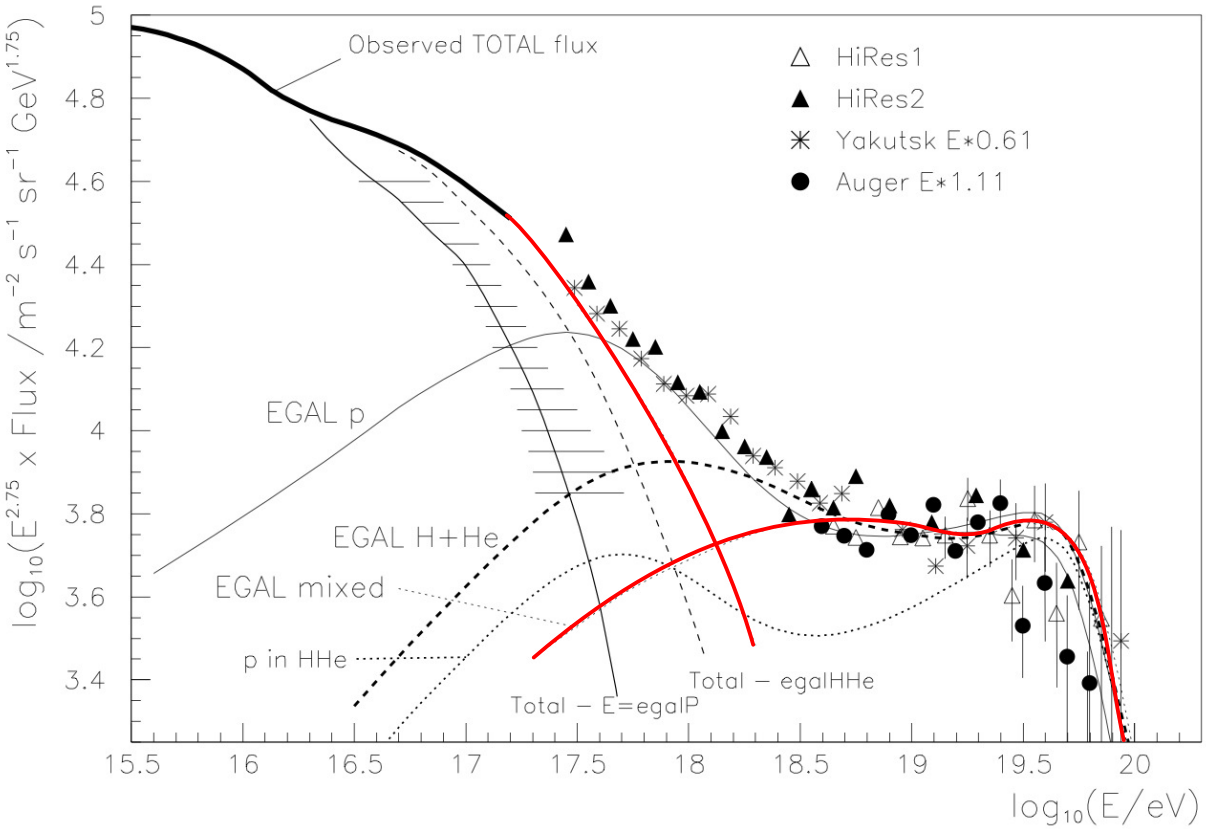
Obertrubach Astroteilchenschule

Alessio Porcelli

October 7th 2011

Spectrum

[A.M. Hillas, astro-ph/0607109]



The CR spectrum: galactic + extragalactic elements;

- Hillas et al.: *Ankle* given by G.-ExtraG. transitions:
  - G.-ExtraG. transition estimation: $log_{10}(E/eV) \approx 18.5$;

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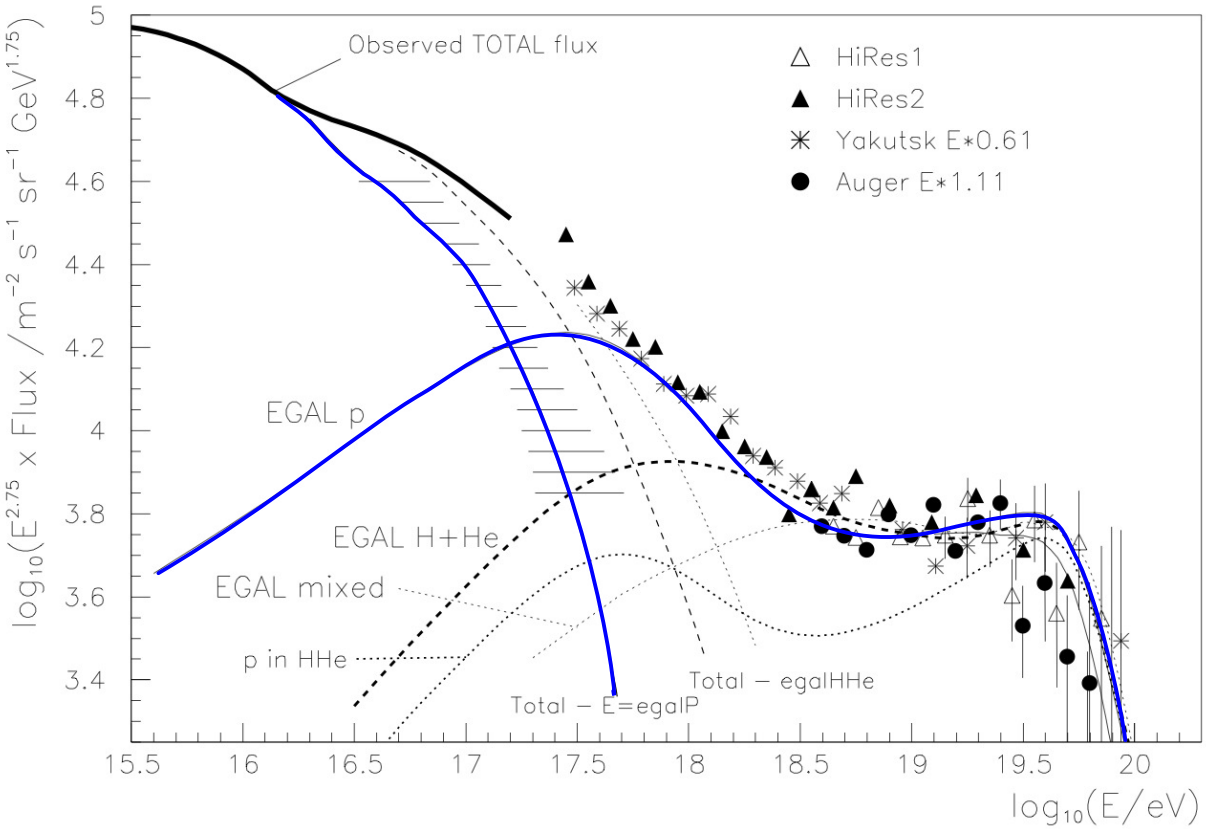
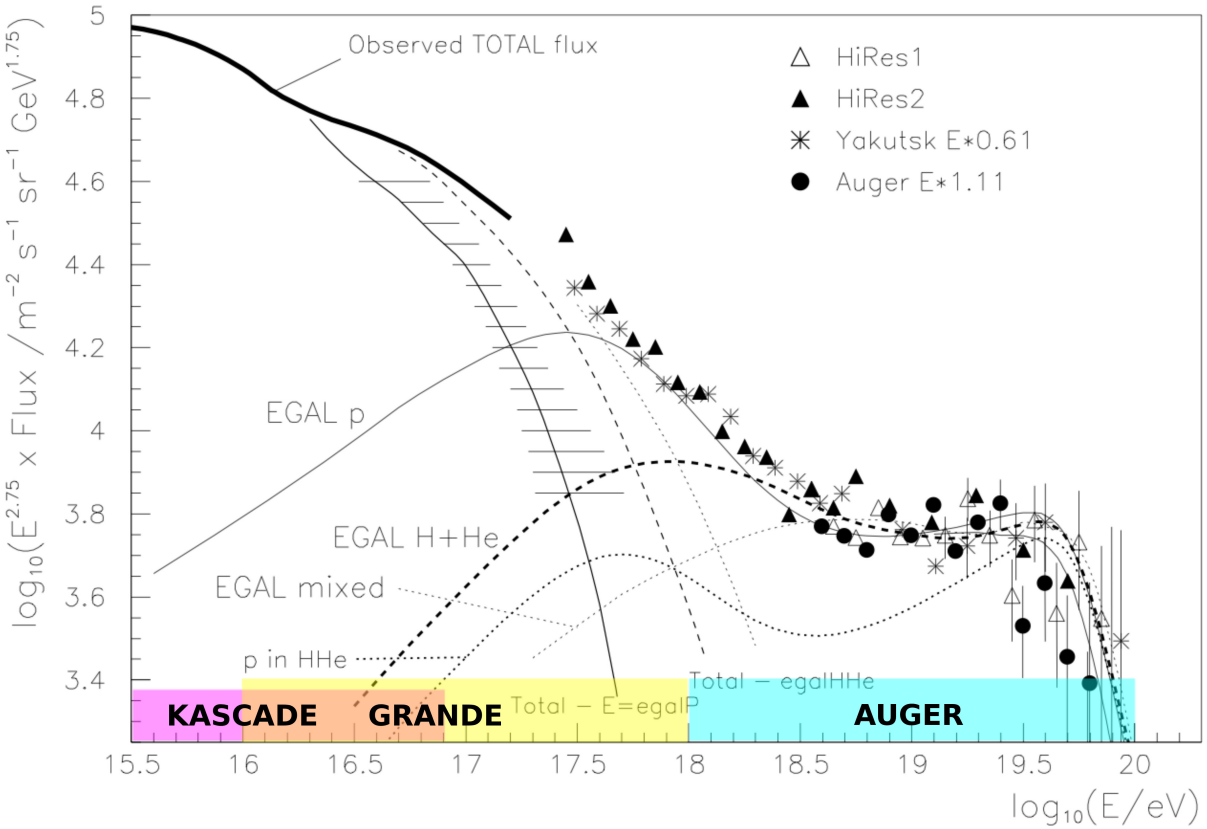


The CR spectrum: galactic + extragalactic elements;

- Berezinsky et al.: *A.* given by E loss $p + \gamma \rightarrow p + e^+e^-$:
  - G.-ExtraG. transition estimation: $log_{10}(E/eV) \approx 17.5$;

Spectrum

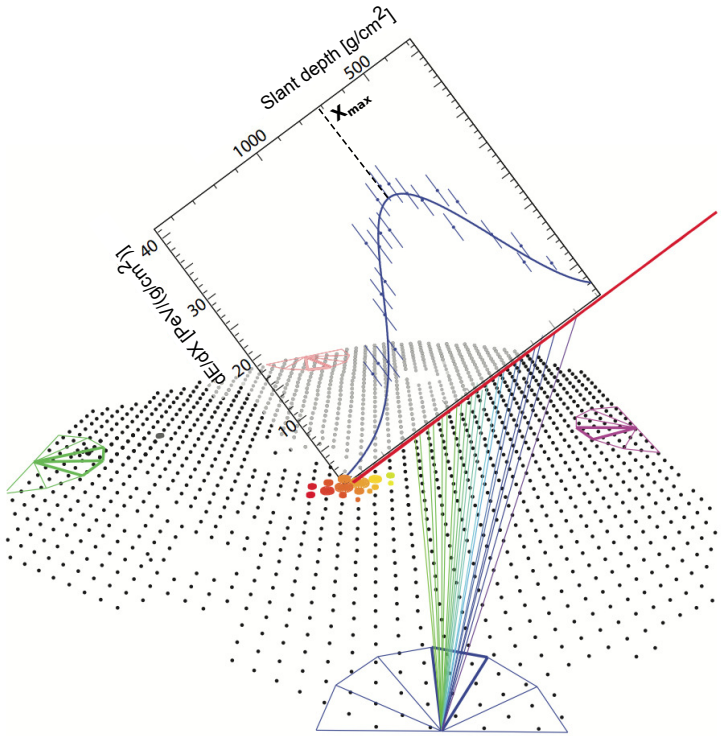
[A.M. Hillas, astro-ph/0607109]



The CR spectrum: galactic + extragalactic elements;

- Transition region is below the *Ankle*:
  - $log_{10}(E/eV) \approx 17.5 \div 18.5$;
  - Region where data are rather sparse.

X_{max}

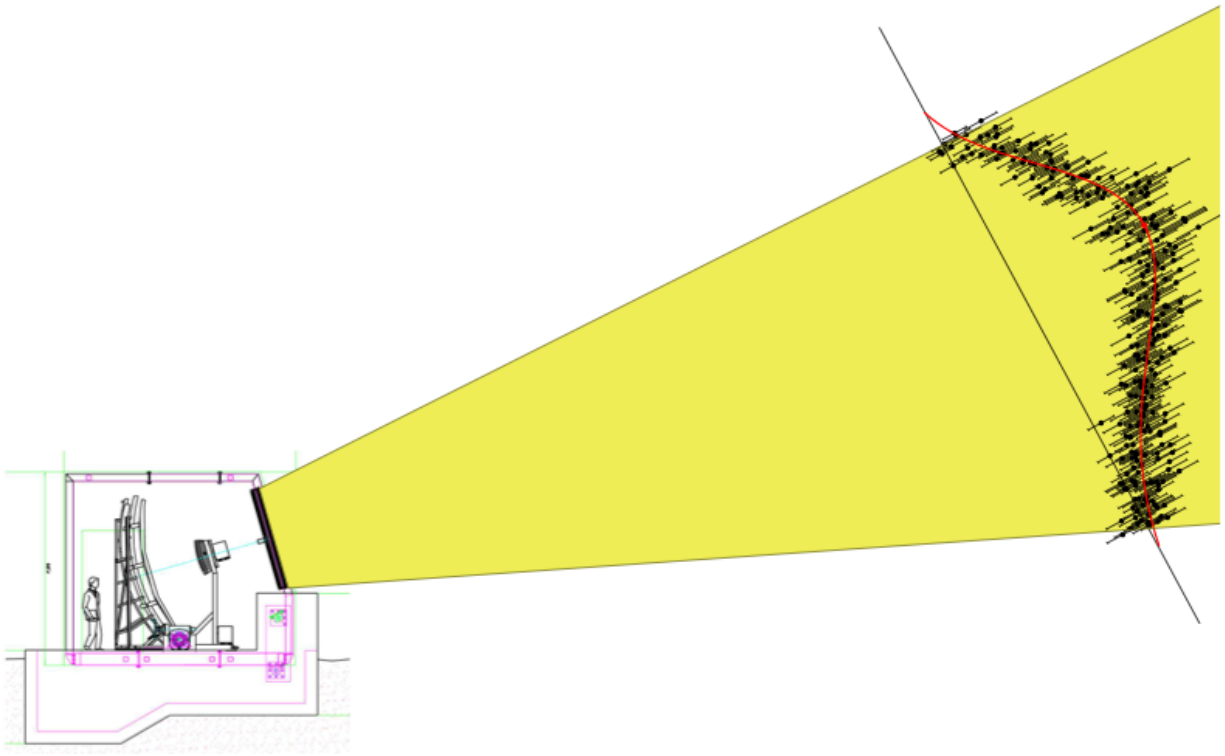


The *Elongation* (X_{max}) of a CR shower is where there is the the maximum longitudinal profile development (energy loss)

- Well know profile (Gaisser-Hillas);
- $\propto \ln A$ (A is the atomic number);

$\Rightarrow$ Experimental observable for understanding the CR composition.

Need for HEAT



With HEAT we have a larger FOV:

- Low energy showers more detectable
- Better explore the transition region between galactic-extragalactic CR

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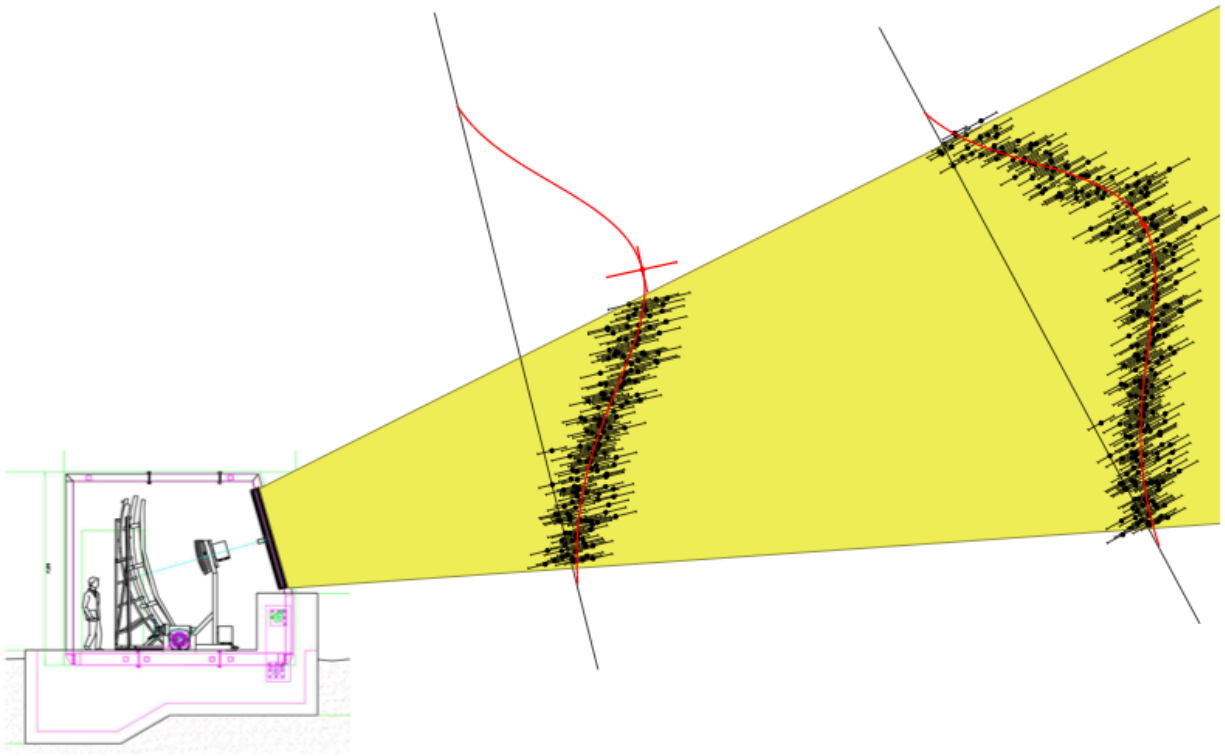

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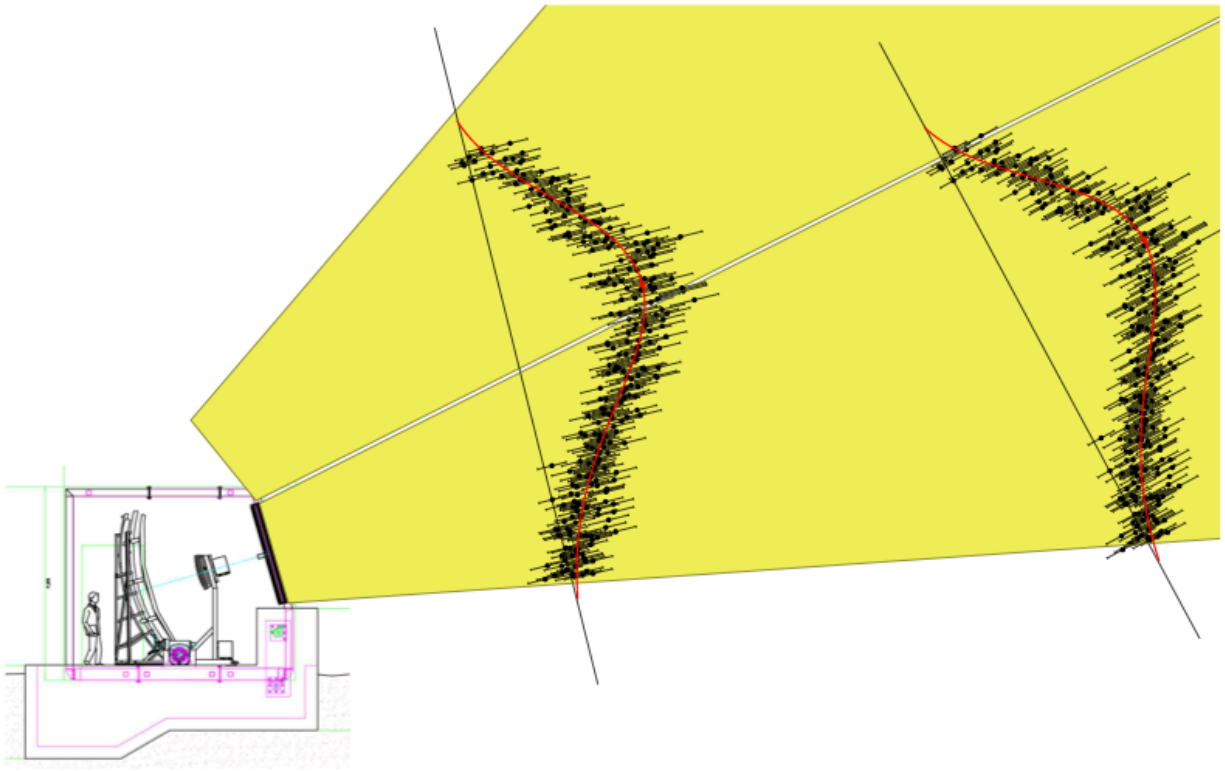

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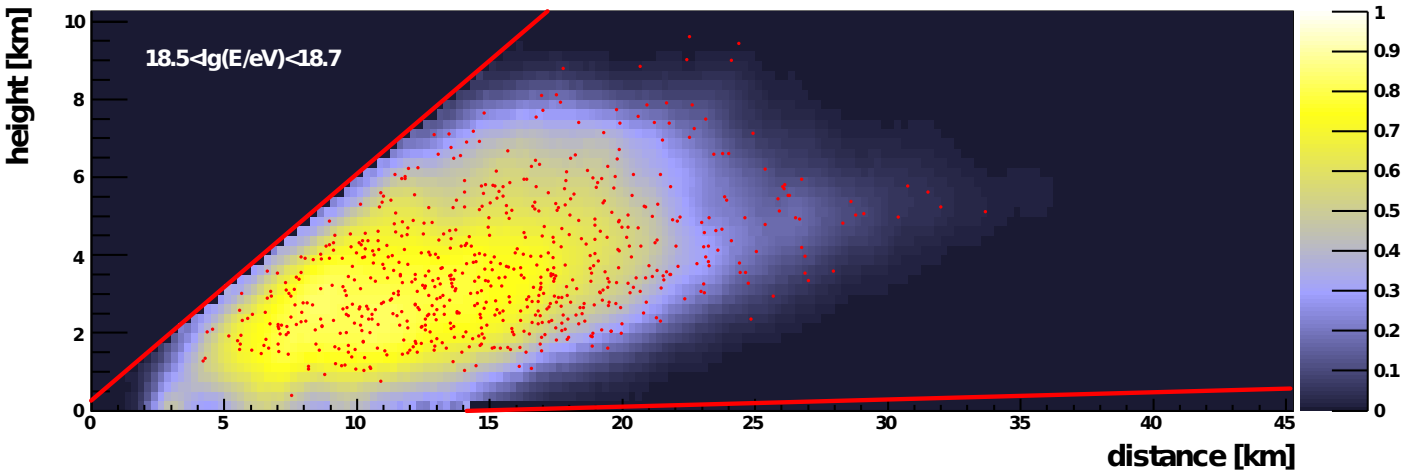
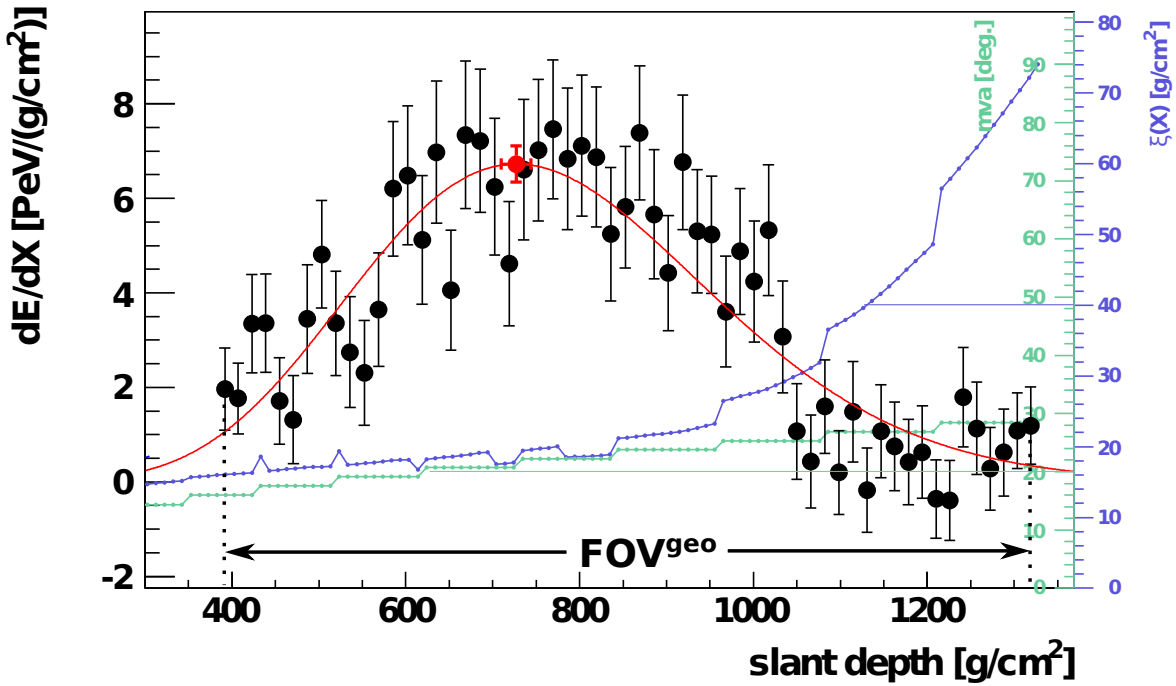
Geometrical and Expected FOV



- Geometrical FOV (inside red lines) delimitated by:
  - telescope viewing ($1.5^{o} \leq \mathrm{FOV} \leq 30^{o}$).
- Expected FOV(colored area) delimitated by:
  - trigger efficiency;
  - detector efficiency (viewing angle of each PMT).

FOVs in details

- Geometrical (dotted vertical lines)
- Expected (dashed vertical lines): must fulfill the conditions
  - Reconstructed X_{max} uncertainty $\xi(X) < 40\ g/cm^2$
    ($40\ g/cm^2$: is statistical uncertainty upper limit)
  - minimum viewing angle $\alpha > 20^o$
    ($< 20^o$: too much Cherenkov light)



[NOTE: picture from conex EPOS simulations]

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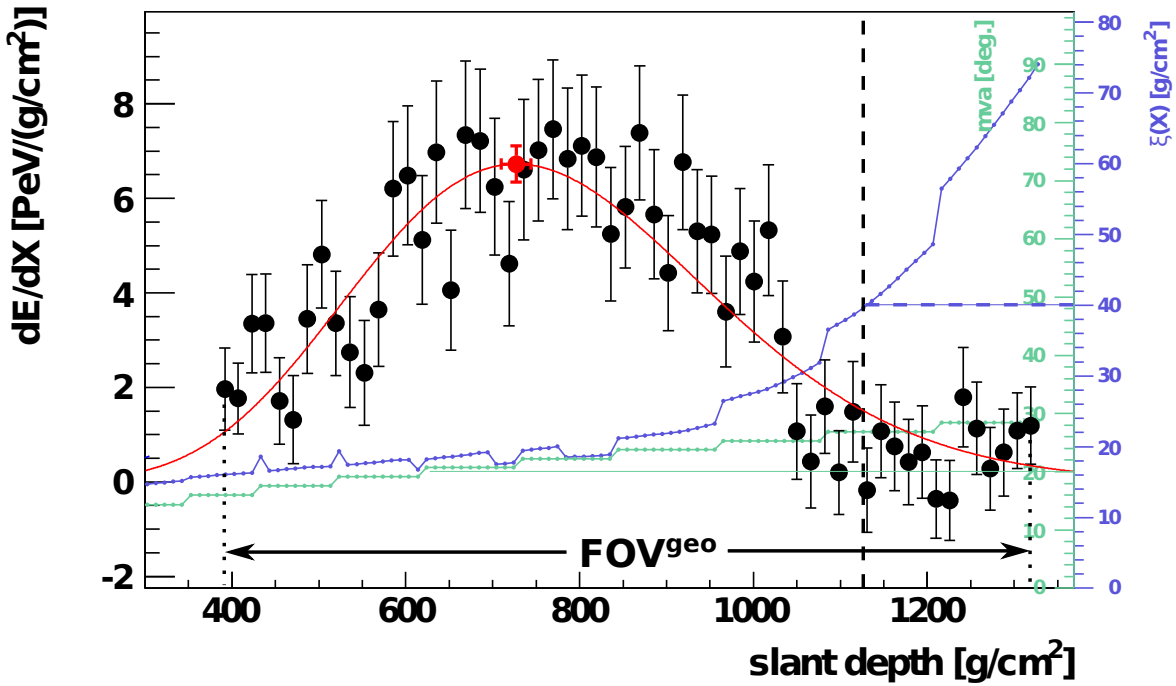

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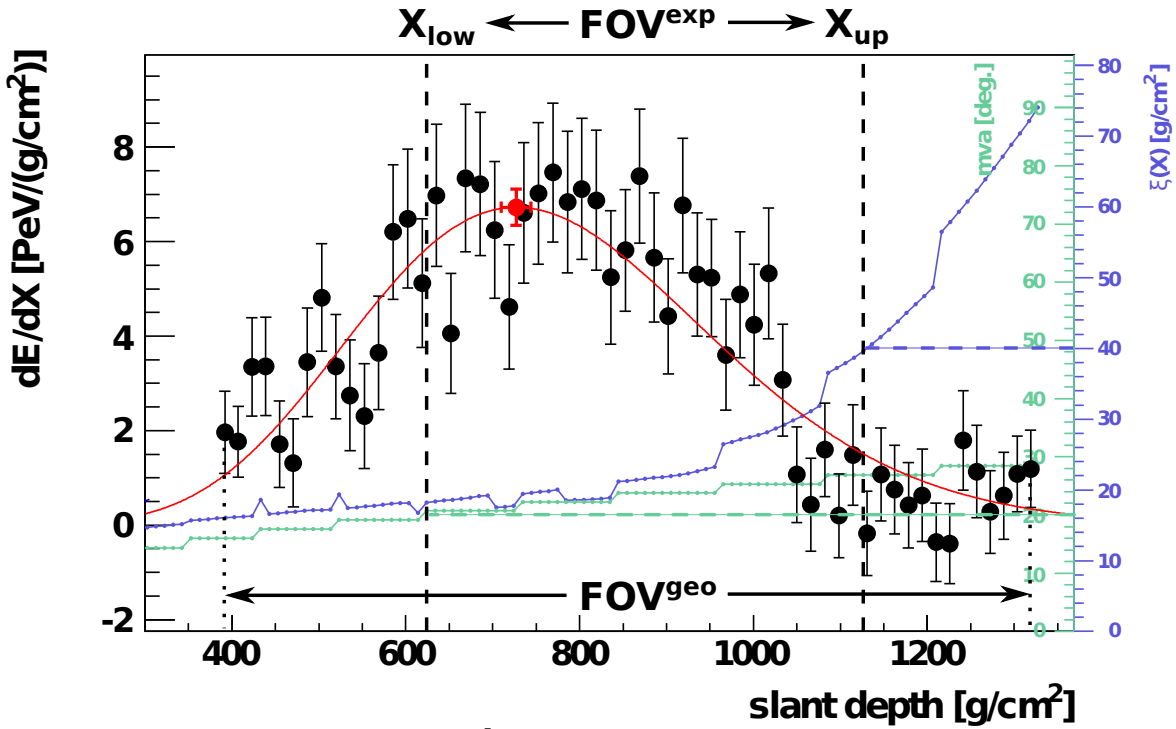

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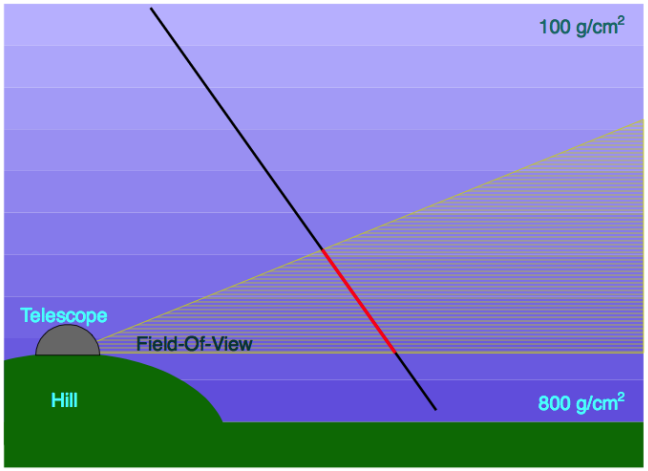
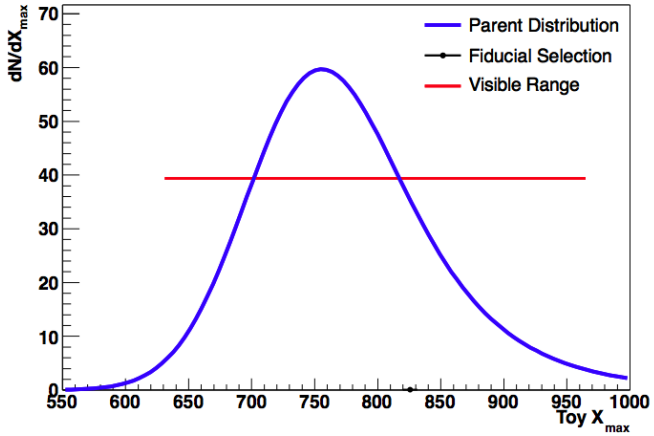
Fiducial FOV

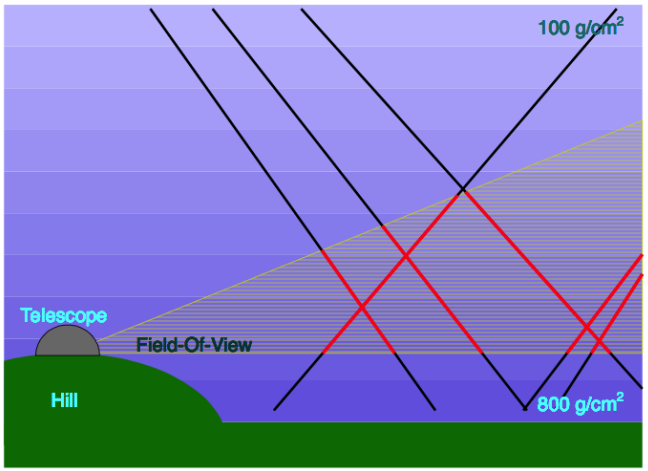


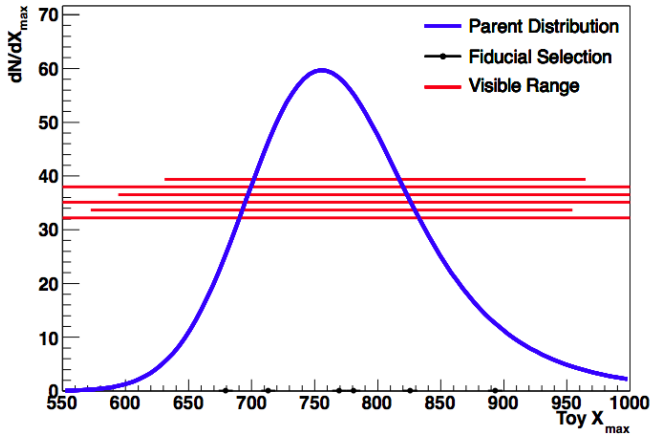


- A shower has a visible range in the FOV (red line);
- Each shower has its own visible range (red lines);
- Putting together all the shower sampled, X_{max} distribution is not correct (X_{max} distribution undersampling).

[Pictures from R. Ulrich (Auger Collaboration), icrc946]

Fiducial FOV





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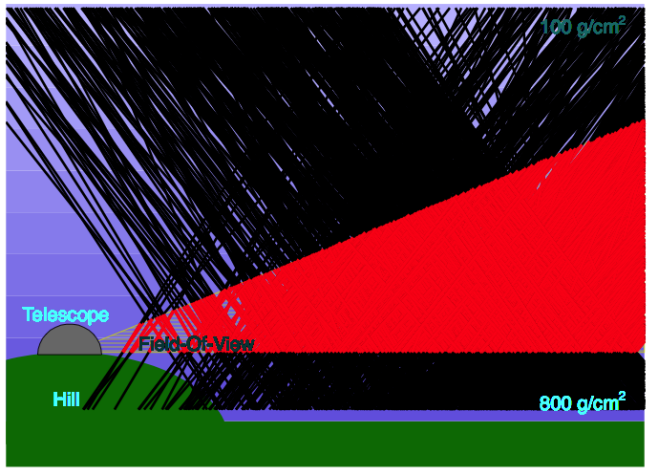

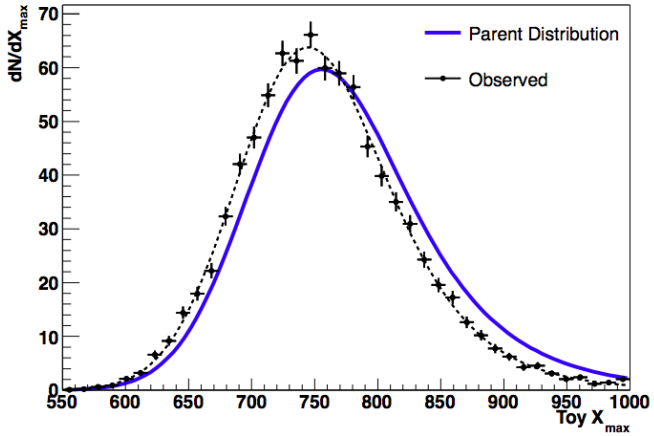

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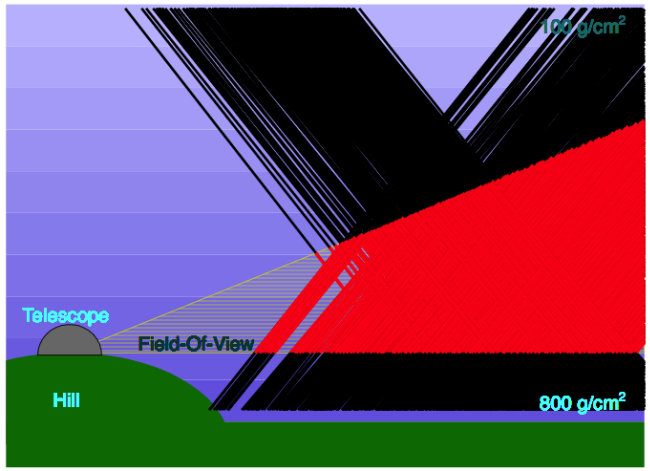

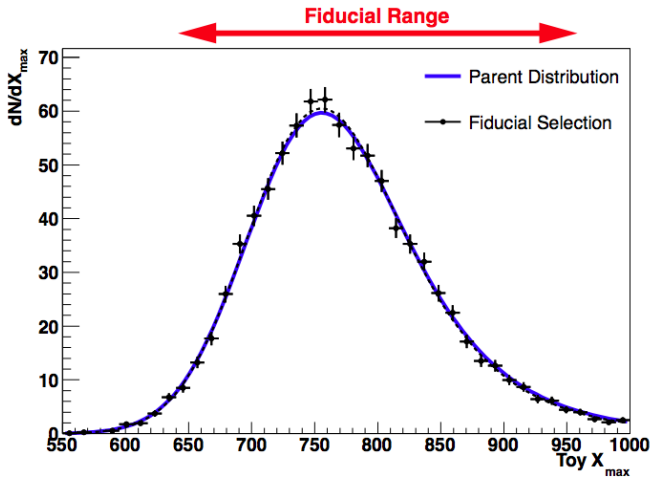

- A shower has a visible range in the FOV (red line);
- Each shower has its own visible range (red lines);
- Need to give a fiducial cut to assure a correct X_{max} distribution sampling: exclude those events with an expected FOV boundaries "inside" the fiducial FOV boundaries ($X_{low} > X_{low}^{fid}$ or $X_{up} < X_{up}^{fid}$).

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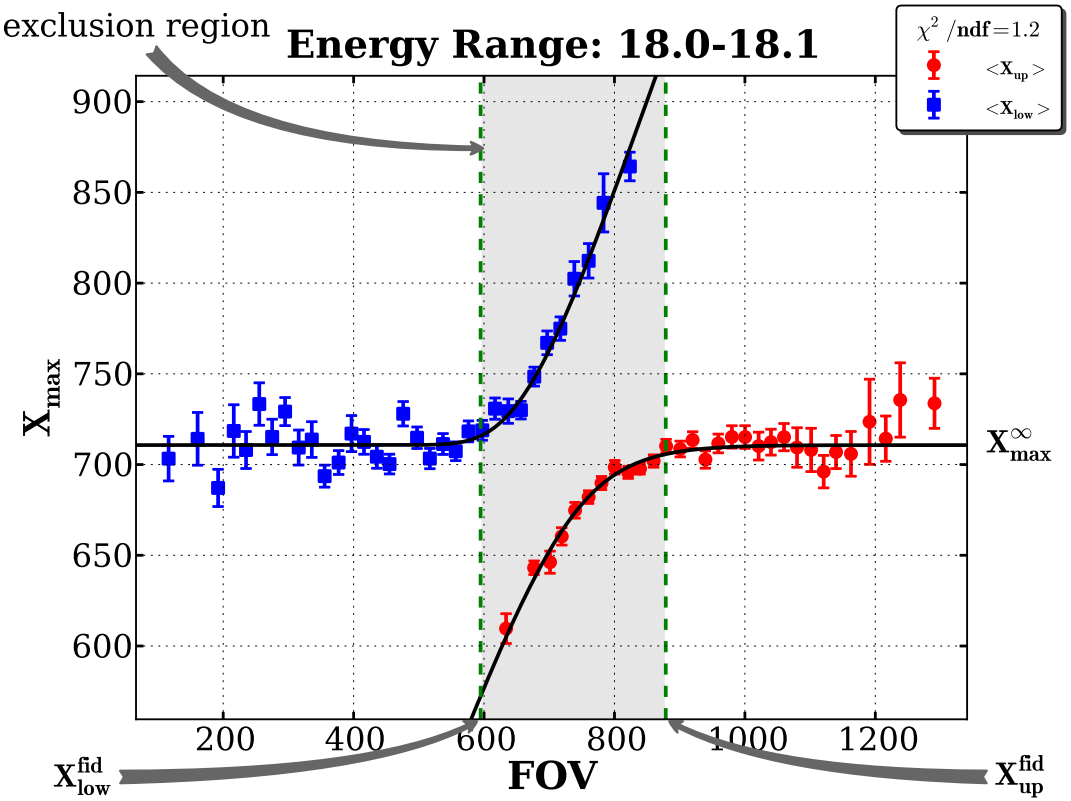
Estimation of the fiducial cut values

$\xi(X)$ and *mva* give X_{low} and X_{up}

for given energy (here: $18.0 < \log \mathbf{E} < 18.1$)

and Δ (systematic uncertainty upper limit; here: $\Delta = 5$ g/cm^2)

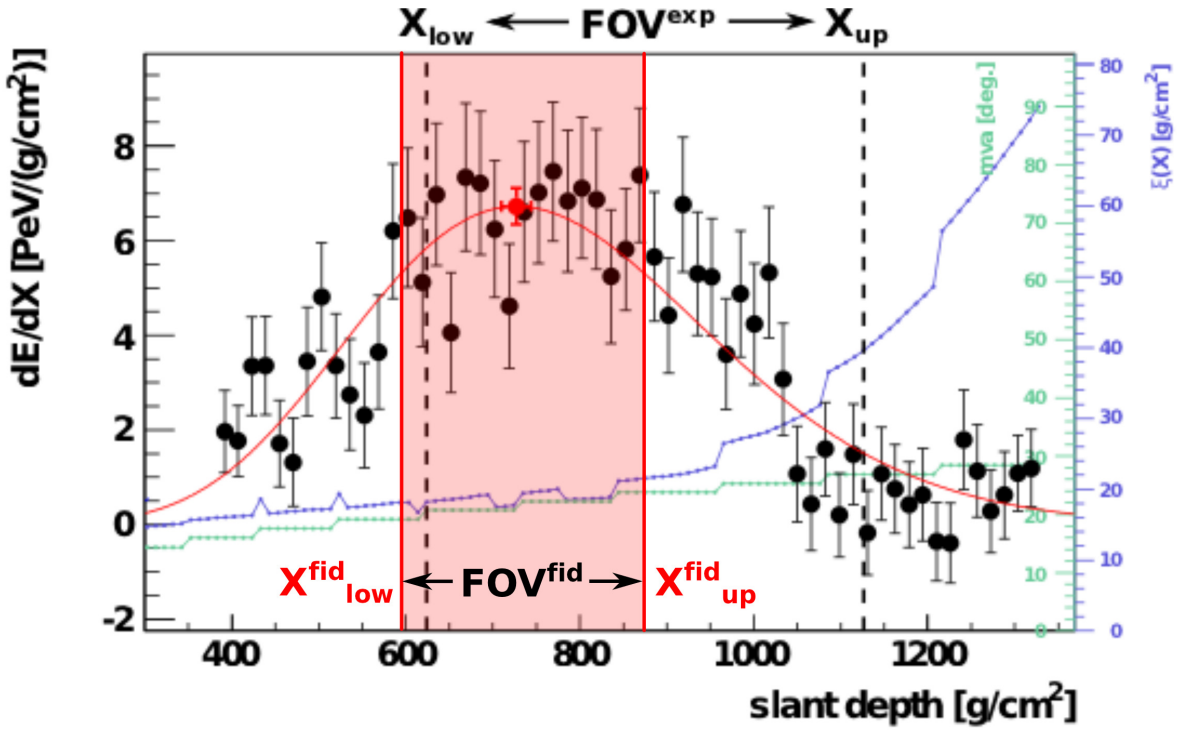


- Region inside the dashed lines is excluded ($\Delta > 5$ g/cm^2)
- The black curve is the mean fit

[NOTE: picture from data]

An instructional example

Just looking at the event before with the $X^{fid}_{low}/X^{fid}_{up}$ just estimated...



- $X_{up} > X^{fid}_{up} \Rightarrow$ OK!
- $X_{low} > X^{fid}_{low} \Rightarrow$ NO!

$\Rightarrow$ This event must be excluded!

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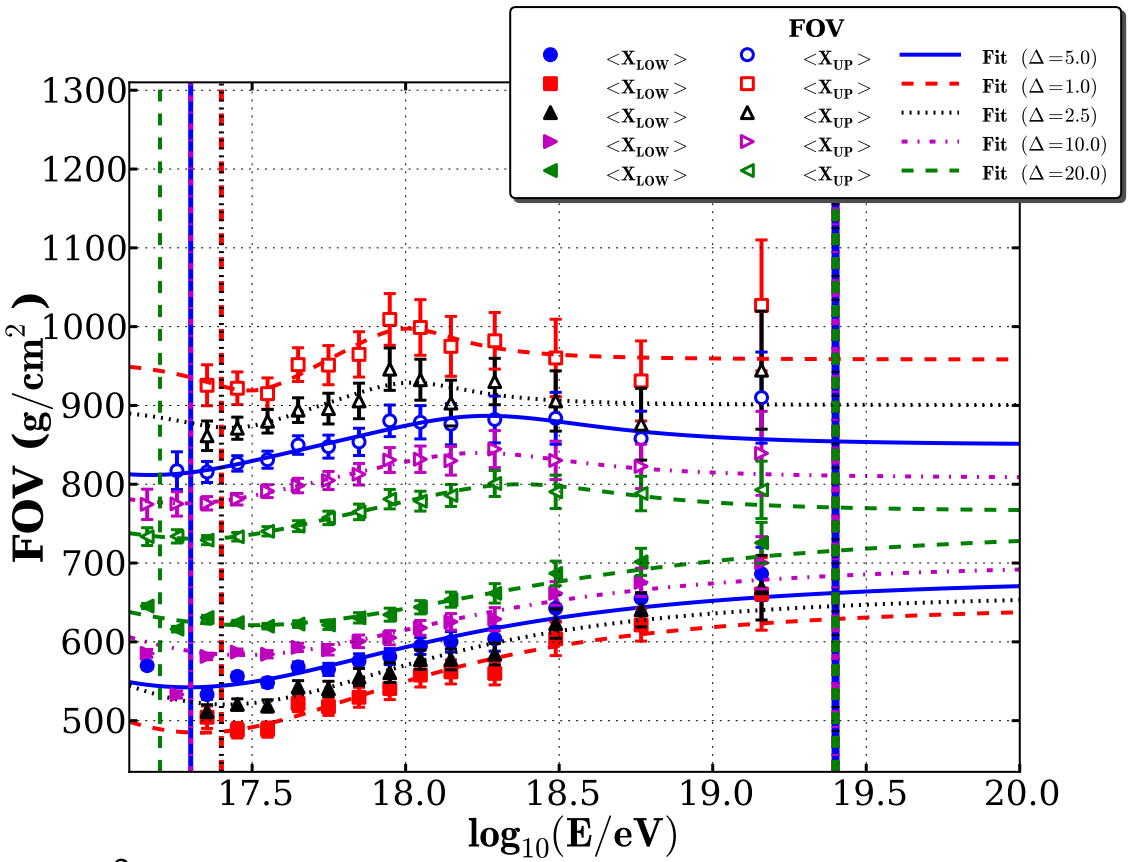
Fiducial FOV selection

To find the boundaries for the FOV cut:

1. Plot $X_{low}^{fid}/X_{up}^{fid}$ for every energy
2. Do fit and parametrization



($\Delta = 5\ g/cm^2$ is usually chosen to have low systematics and not lose too many events.)

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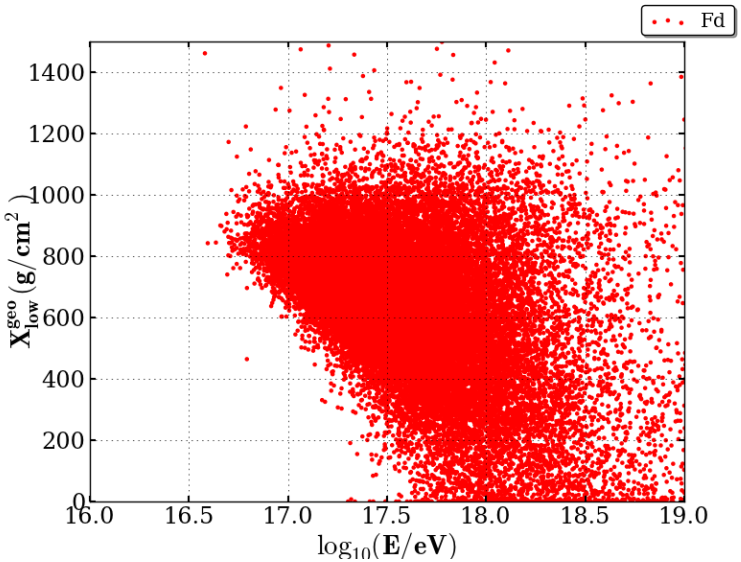
Conclusions

- With only Fluorescence Detector (FD):
  - ☺ Reached $\log_{10}(E/eV) \approx 17.5$;
  - ☹ Many events lost.



- HEAT+FD (HeCo) expectation:
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  - Increase events in the region where data are rather sparse.

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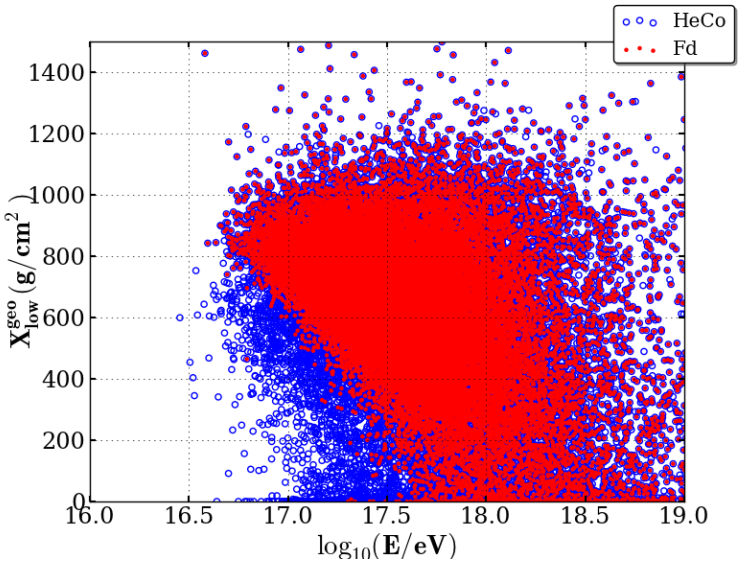

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